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Technical report (interim) for AFOSR 91-0342, "Eye movements and visual information processing"

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Overview. The work done in my laboratory over the past 10 years has been devoted to understanding the relationship of sensory and cognitive factors in the control of smooth and saccadic eye movements. The central goal of the project funded by the current grant is the understanding of how saccadic eye movements are used to accurately localize objects in space.

Explaining accurate localization is a real problem because the objects we choose to look at are relatively large -- typically extending over several degrees of space -- but the saccadic eye movement must land at one place within the target. Our published research suggests that the computation requires a sequence of two stages: (1) voluntary attentional weighting of information in the visual display, and (2) automatic spatial-pooling of the weighted information (He and Kowler, 1989; 1991). Below is a summary of our current research on each of these two stages, the attentional stage and the pooling stage.

Attentional stage. The question we are addressing is: does a single attentional filter determine the input to both perception and eye movements, or is a dissociation of saccades and perceptual attention possible? The prior literature has been inconclusive because of methodological difficulties in the experiments.

We have been studying the link between saccades and attention by examining the effect of a cue, which summons attention, on the programming of saccades. We present 8 characters arranged in a circular array (radius= 2 deg). Presentation time is brief (100 msec) and pre- and post-stimulus arrays are presented to act as masks. One of the 8 characters is the cue (a numeral) and the rest are letters. In some trials the subject's task is to look at the cue while in other trials he has to look at the opposite location. Separate psychophysical experiments verified that the cue summons attention: we found that the accuracy of identifying a second numeral, presented in an array that follows the first, is better if the numeral appears at the cued location than when it appears at the opposite location.

The saccades were affected by the summoning of attention. Saccadic latencies were about 30 msec shorter when saccades were directed to the cue than when they were directed to the opposite location. We interpret this difference in latency as, first, showing that saccades and attention are indeed linked and,

second, showing that the time required to shift attention from the attended cue to the opposite location is only 30 msec. We have submitted an abstract to ARVO describing this result.

We are extending this work in ways that will lead to a model of how the allocation of attention constrains saccades:

(1) We are combining our oculomotor and perceptual tasks and studying the ability to recognize a numeral presented after the cue, while saccadic programming is in progress. So far, we have observed a small improvement in perceptual performance for targets located at the goal of the saccade. This result is consistent with a link between saccades and attention, but perceptual performance remains so good at locations other than the saccadic target that it may well turn out that the attentional demands of saccades are modest. Such a result would mean that only a small shift in attentional weighting is sufficient to determine the endpoint of saccades and human beings are for all practical purposes able to acquire and process new information from various portions of the visual field even as they prepare a particular pattern of saccadic movements.

(2) We are planning to vary the number of cues and the locations of the cues to find out where saccades land when attention is distributed over large regions of space. Do saccades land at the center of the attended region or is there some competition between attention locations so that saccades land near only one of the cues?

Spatial-pooling. The second major phase of the research deals with the proposed spatial-pooling process that takes information in a selected (attended? see above) region and computes the saccadic endpoint. Our goal here is to develop a model which specifies the information processing stages used to compute the saccadic endpoint.

Experiments completed so far (Kowler and Blaser, 1992) showed that saccades made to single point targets or to spatially-extended targets (outline drawings of circles or diamond-shaped configurations of 4 points) are remarkably accurate and precise. We did not find the systematic undershoots that are described in the oculomotor literature and we found that spatial precision was nearly as good as the high-level of precision characteristic of perceptual localization (SDs=6% eccentricity). This result implies that there is no loss in saccadic performance when going from a small target point, where the saccadic endpoint is specified precisely, to a large target form, where the endpoint has to be determined from the information in the target. We concluded that a spatial-pooling process must exist that automatically and effortlessly determines saccadic endpoints within target forms. Moreover, the high level of performance we observed means that we have succeeded in minimizing saccadic errors due to extraneous behavioral factors and now makes it possible to study underlying sensory-motor

relationships.

In our current work we are about to begin studying saccades to different patterns of random dots. We want to know whether saccades land at the center of gravity of the dot pattern or whether dots near the contour are given greater weight in determining where the saccade lands. If the saccadic landing position is not determined by a straightforward computation of the center-of-gravity, we will try to specify the weighting function that may be applied to the dot pattern before the locations are averaged. This work will be done in collaboration with Prof. C. Chubb at Rutgers. We want to know whether the mathematical technique of "histogram contrast analysis", which he developed and applied to texture discrimination, will be able to reveal the characteristics of this proposed weighting function.

We also plan to study the distributions of saccadic landing position as a function of stimulus size, contrast and spatial frequency content. These experiments are being planned in collaboration with Drs. J. Bergen and J. Lubin at Sarnoff Labs in Princeton. They have developed a model of visual processing to account for perceptual discriminability of eccentric characters. We believe that their model will serve as a good starting point to model the spatial pooling process. I have submitted an AASERT proposal requesting funds for students who will receive interdisciplinary training in vision (psychology + engineering and mathematics) to work on this collaborative project.

Other projects. Two papers appeared or are in press. One showing that saccades are required, and attentional shifts are inadequate, for perceiving texture patterns that do not readily segregate (He and Kowler, 1992). The second solved a long-standing problem in oculomotor control by showing that slow control eye movements serve to keep retinal images stable rather than to bring eccentric targets to an optimal retinal locus.

#### Publications

He, P. and Kowler, E. (1992) The role of saccades in the perception of texture patterns. Vision Res., 32, 2151-2163.

Epelboim, J. and Kowler, E. (1992) Slow control with eccentric targets: Evidence against a position-corrective model. Vision Res., in press.

#### Talks

Kowler, E. and Blaser, E. (1992) The spatial precision of saccades. ARVO, May, 1992.

#### Colloquia

"Eye movements in the natural world." University of Rochester, March, 1992 and Rutgers University, Newark, March, 1992.